Potential of Low-grade Kaolinitic Clay as a Cement Substitution in Concrete

Kwabena Boakye, Morteza Khorami

Faculty of Engineering, Environment & Computing, Coventry University, UK

Abstract

Metakaolin, produced from pure kaolinitic clays have been used as a supplementary cementitious material (SCM) over the years due to its technical benefits. However, the availability of pure kaolinitic clays remain a challenge since it can be found in only specific areas. This work, therefore, investigates the potential use of less pure kaolinitic clays, which is found almost everywhere, as SCM for construction purposes. XRF, XRD and TG/DSC analysis were conducted on the clay. The clay was calcined at 600 °C and used to partially replace ordinary Portland cement by 10 wt.%, 20 wt.% and 30 wt.%. Compressive strength was found to decrease as calcined clay content increased.

Introduction

Supplementary cementitious materials (SCMs) have become an integral part of concrete due to the technical and environmental benefits associated with them. Notable among SCMs is fly ash, obtained from coal-fired power plants. There are, however, concerns about the availability of fly ash in recent times due to the decline in coal-fired power generation plants, with a full closure projected by 2025 [1]. This has necessitated the exploration and potential use of other materials such as naturally occurring kaolinitic clays to replace fly ash in concrete. This research studies the potential use of less pure kaolinitic clay as a supplementary cementitious material for concrete applications.

Methodology

- The clay sample was calcined at 600 °C for 3 hours at a heating rate of 10 °C/min and milled to cement fineness.
- CEM-I (52.5N) cement was partially replaced with the calcined clay powder in weight percentages of 10 wt.%, 20 wt.% and 30 wt.%.
- 50 × 50 × 50 mm mortar cubes were prepared according to methods specified by BS EN 196-1:2016, using a cement to sand ratio of 1:3 and water/binder ratio of 0.5.
- The mortar cubes were cured under water and their respective compressive strengths determined after 3, 7 and 28 days.

Results

XRF and XRD analysis are seen in Table 1 and Fig. 1 respectively. TG/DSC, setting time and compressive strength results are also shown in Figures 2, 3 and 4 respectively.

Table 1: Chemical composition of raw materials

Oxides	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	SO_3
Clay	59.95	0.82	6.51	1.3	0.14	1.6	1.29	0.07
CC	40.54	28.75	25.42	1.40	0.25	0.20	1.07	0.19
CEM-1	21.0	4.4	2.7	1.6	66.7	0.6	1.99	2.27

CC: Calcined Clay

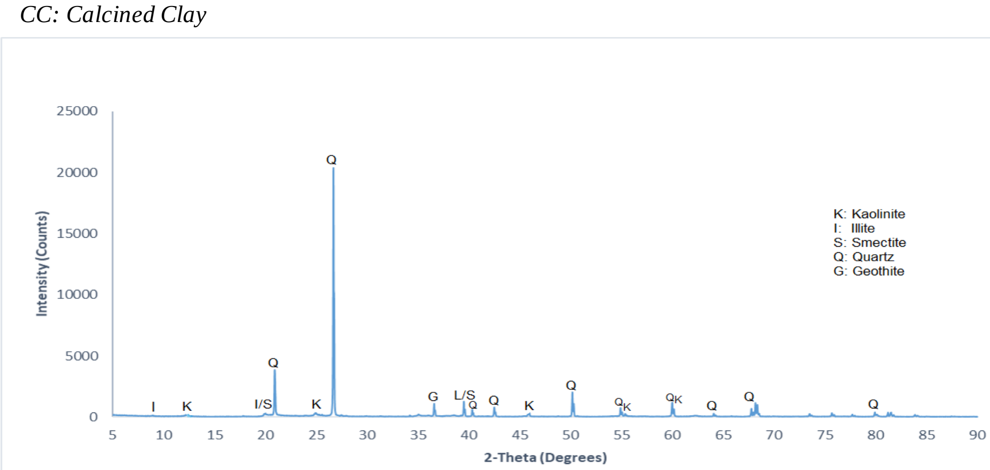

Fig. 1: XRD of clay

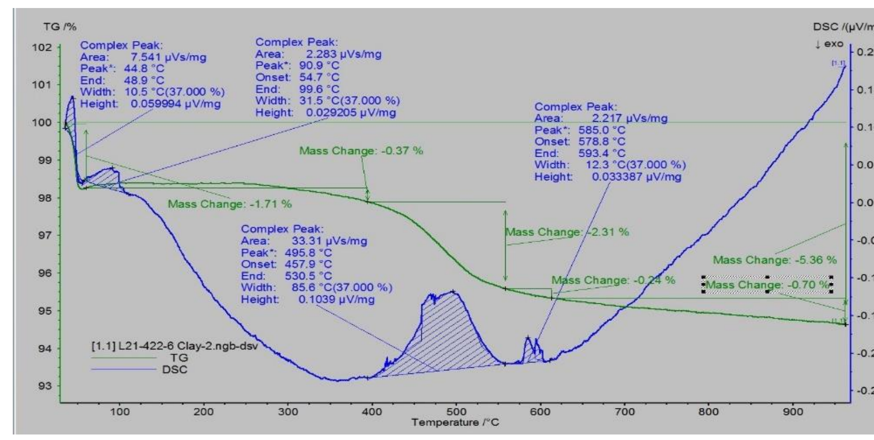

Fig. 2: TG/DSC analysis of raw clay

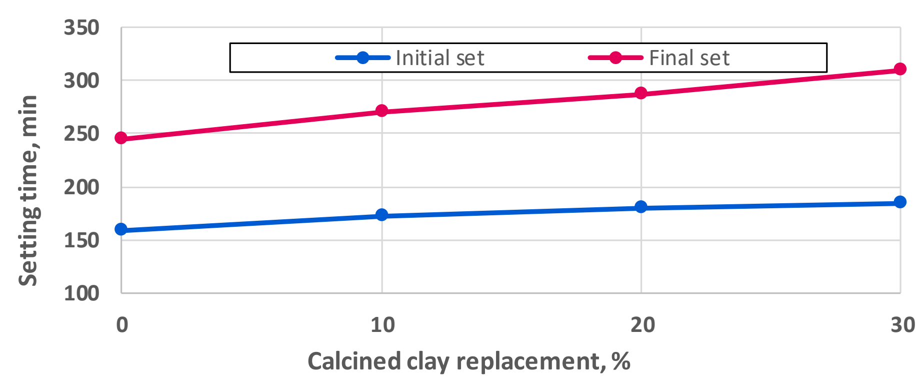

Fig. 3 Setting time of cement with varying calcined clay content

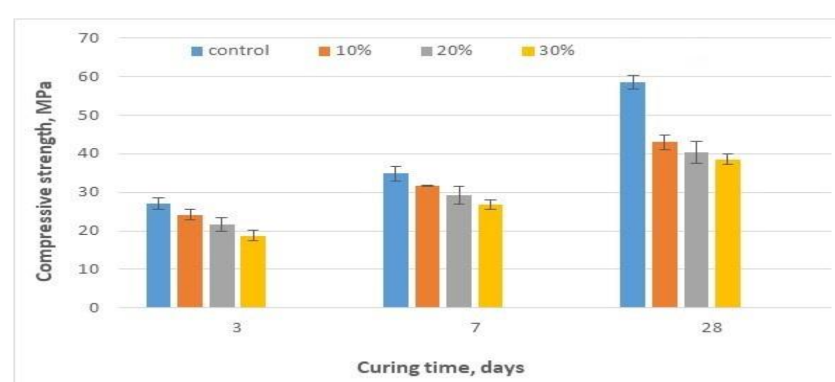

Fig. 4 Compressive strength containing calcined clay

Conclusion

- The studied calcined clay possesses the requisite oxides in their right quantities and qualifies to be a pozzolan, even though its purity is quite low. XRD results revealed the presence of kaolinite, illite and montmorillonite in the clay. Kaolinite content in the clay was estimated to be 17%.
- Setting time increased as calcined clay content increased.
- Compressive strength decreased with increasing calcined clay content. Replacing with 20% could be comparable to Class 42.5N cement.

Reference

[1] McCarthy MJ, Robl T, Csetenyi LJ. 14 - Recovery, processing, and usage of wet-stored fly ash. In: Robl T, Oberlink A, Jones R. Coal Combustion Products (CCP's). Woodhead Publishing; 2017. p. 343-67.